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AN ASSESSMENT OF AGRICULTURE CANADA'S PROGRAM ON ENERGY CROPS AND BIOMASS COMBUSTION

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EXECUTIVE SUMMARY

The energy crops and biomass utilization portion of the ERDAF program analyzed the potential of agriculture to supply all or some of its energy requirements from the biomass produced from agricultural land. A perceived abundance of waste biomass, surplus land suitable for energy crop production, and the existence of applicable technology made agriculture an obvious choice for renewable energy research. The program allowed those involved to critically examine the concept of biomass energy production in agriculture from a holistic perspective.

Energy crop biomass yields were not significantly different from biomass yields of conventional crops, contrary to initial expectations. Optimum agronomic practices including time of planting, planting density, fertilizer response, harvest date, and herbicide resistance would require many years to develop. The use of marginal land, while avoiding the food versus fuel debate, also provided marginal yields as the quality of the land had a direct bearing on the yield. The toxic or allelopathic effect of successive crops was not determined and many years of research would be required before rotations based on energy crops could be recommended.

The identification and development of kochia as an alternative forage crop for marginal lands was a major spinoff of the energy crop program. Research and development of kochia is continuing based upon its ability to survive on and reclaim saline soil, its palatability to livestock, and its nutrient content. Jerusalem artichokes also benefited from exposure through the program and could become a future source of fructose sugar or simply another health food product because of some of its unique properties.

Cereal chaff was identified as a significant source of biomass energy available at a low environmental cost. Although its use as a combustible energy source has proven uneconomical, chaff collection has been reviewed because of the potential for reducing volunteer grain and weed competition. Also, chaff can be easily converted into a medium quality animal feed. Further work on improved collection systems, ethanol fermentation processes, feed conversion methods, and agronomic impacts of chaff and its removal is required before chaff can be fully exploited.

Pyrolysis and direct combustion technologies were investigated and several problems found. Automation of the conversion process was made difficult by the non-uniformity of the biomass and the corresponding handling difficulties that this characteristic caused. Storage and transportation costs and the low cost of conventional energy sources made biomass combustion technology uneconomical. Burner designs were often found to be lacking in reliability and safety with the possible exception of the SUKUP burner. It performed as specified and has been proven in the agricultural environment.

The program clearly demonstrated that all aspects of biomass utilization must be considered including collection, transportation, storage, burner feeding systems, and combustion mechanisms. Alternative energy sources must compete not only with the cost of oil, propane, natural gas, and electricity but also with the convenience of conventional sources.

The surveys of available agricultural biomass suitable for energy production did not successfully identify any major underutilized biomass resources or technologies. Agriculture has the potential to become more energy efficient and, theoretically, self sufficient but there is little economic incentive to do so. Agriculture will therefore continue to depend heavily on conventional sources of energy. Conservation is still the best option to help agriculture cope with its energy needs.

INTRODUCTION

Agriculture Canada established an energy research and development initiative in 1981 called the Energy Research and Development in Agriculture and Food (ERDAF) program. ERDAF was a contracting out program that evolved from the Agricultural Engineering Research and Development (AERD) program. ERDAF was broad in scope, including basic research, product development, and demonstration. The funds for the program were provided under the federal energy research and development program managed by the interdepartmental Panel on Energy Research and Development (PERD).

This report is a review and assessment of the work performed in the development of energy crops and the utilization of agricultural biomass as an energy source through combustion and related technologies. It complements similar reports on anaerobic digestion(Van Die 1987) and liquid fuel production (Van Die et al., 1988). These three reports cover the contract research performed for Agriculture Canada which addressed the production and utilization of agricultural biomass for energy purposes. The reports are not meant to be a rigorous treatise on the subjects they cover as they are limited to a review of the completed contract work under the ERDAF program. Related work was sponsored by other departments and programs such as the Natural Sciences and Engineering Research Council (NSERC). There was additional research undertaken and sponsored by organizations and institutions outside the federal government which should also be reviewed to obtain a total perspective of biomass production and utilization for energy in Canada.

BACKGROUND

The possibility of growing crops solely for energy purposes was appealing for several reasons: if grown on marginal land, energy crops would not compete with food production, innovative agronomic practices could be used to bring marginal land into production, agriculture could become more self-sufficient in energy, and new markets for agricultural production would be created. The development of energy crops was therefore an important aspect of the energy program and captured the interest of many researchers. The ERDAF program was valuable in that it provided reliable yield data on many 'wonder' crop varieties. Agriculture Canada is always interested in exploring new crops to improve productivity and farm incomes; the energy crop program fitted within this mandate.

The combustion of agricultural biomass was appealing as a replacement or supplement for petroleum products, especially when the biomass was a byproduct of normal food production such as straw from grain. This encouraged the consideration of biomass combustion to offset the energy cost increases and shortages anticipated at the start of the ERDAF program. The technology of burning agricultural biomass was actively researched and has been commercialized in Europe because of their higher relative energy costs. Biomass combustion can occur without mechanical intervention, but control, reliability, and utilization of the heat energy produced proved difficult. Many attempts were made to build and operate biomass burners but most ended in premature failure. Most of these were private ventures and little documentation exists on them.

DISCUSSION OF PROGRAM RESULTS

RESOURCE ASSESSMENT

Responding to specific informational needs of the program and the public, a series of contracts was undertaken to assess the amount of agricultural biomass available for fuel and fiber on a sustained basis nationwide. Current levels of food and feed production could not be adversely affected. Two scenarios, one five year term and one ten year term were considered. Many previous studies had looked at specific areas or certain materials and used different methodologies to predict availability. The ERDAF studies developed a disaggregated inventory of potential feedstocks. The feedstocks were evaluated in terms of the energy forms of the end products considering available conversion technology, economics, and any other constraints. From this information, regional energy production estimates were made.

The feedstocks were assembled into the following groups: crop residues, crop culls, agricultural processing wastes, farm wastes, and production due to increased productivity from existing and potential agricultural land excluding commercial forestry land.

The surveys did not identify any major underutilized biomass resources or technologies. Therefore, agriculture cannot be considered as a significant potential supplier of energy to economic sectors outside agriculture. A summary of the findings of the studies was contained in the report "The Potential for a Sustained Energy Supply from Combustible Crop Residues in the Canadian Agriculture and Food System -A National Assessment- ", by Dr. H.T.M. Colwell, available from the Policy Branch of Agriculture Canada.

Cereal chaff was identified as a significant source of biomass energy available at a low environmental cost. Although its use as a combustible energy source has proven uneconomical, chaff collection has been reviewed because of the potential for reducing volunteer grain and weed competition. Also, chaff can be easily converted into a medium quality animal feed. Further work on improved collection systems, ethanol fermentation processes, feed conversion methods, and agronomic impacts of chaff and its removal is required before it can be fully exploited. Collection systems for using the chaff as animal feed is now developing rapidly in the private sector.

ENERGY CROPS

The United States Department of Agriculture conducted a comprehensive screening program of crops that could be considered for hydrocarbon production with a goal of future self-sufficiency in energy and basic raw materials. The Agriculture Canada program used the results from this work and supported the evaluation of several plant species that showed promise in our environment. The energy component of the crops took different forms: extractable oil, fermentables for alcohol, and fiber for combustion.

Several species of plants were grown at a number of locations in Canada. This agronomic work was closely associated with similar ongoing research conducted by Agriculture Canada at its research stations. Traditional crops such as corn, wheat, and potatoes were not considered specifically as energy crops although they undoubtedly had considerable potential. The major difference between energy crop and food crop development was that the focus was energy production for mechanized applications.

It was found that energy crop biomass yields were not significantly different from biomass yields of conventional crops, contrary to claims made by proponents and initial expectations. This is not surprising since energy and conventional crops must be produced under the same inherent constraints on biological growth imposed by nature. Errors in yield estimates found in the literature are usually caused by extrapolations of yields from carefully nurtured small experimental plots and are not based on the harvested yield of a significant acreage, (i.e. scaling errors). Optimum agronomic practices including time of planting, planting density, fertilizer response, harvest date, and herbicide resistance require many years to develop. The use of marginal land, while avoiding the food versus fuel debate, also provided marginal yields as the quality of the land had a direct bearing on the yield. Instances occurred where some energy crops could not even survive because of the low fertility of marginal land and weed competition. The toxic or allelopathic effect of successive crops was not determined and several years of research would be required before rotations incorporating energy crops could be recommended.

The program assessed prospective energy crops using biological or microbiological assay methods. Plants possessing toxic components were rejected because the residual biomass could not be readily used by conventional agriculture without expensive pretreatment. Some varieties, such as lunaria, were rejected because they proved unsuited to the Canadian climate. Cattails were rejected as a viable energy crop because the acreage suited to production, though considerable, occurred in scattered locations and large scale cultivation would therefore be economically impossible. Chemical or petrochemical uses of agricultural biomass were assessed in the case of milkweed only, and future opportunities may exist for such applications of this crop.

The identification and development of kochia as an alternative forage crop for marginal lands was a valuable spinoff of the energy crop program. Research and development of kochia is continuing based upon its ability to survive on and reclaim saline soil, its palatability to livestock, and its nutrient content. Jerusalem artichokes also benefited from program results and could become a future source of fructose sugar or other special health food products.

Research has shown that it is technically feasible to isolate an enriched protein from agricultural biomass and some biomass conversion processes. Transportation cost, dispersion of potential consumers, cost of separation, and the lack of commercial demand for protein were factors limiting development of protein separation technology. Competition from existing sources of protein available to agriculture make future development of the technology unlikely in the short to medium term.

DIRECT COMBUSTION AND PYROLYSIS

Pyrolysis and direct combustion are old biomass conversion technologies that have been bypassed due to the advent of low cost convenient fossil fuels. The program clearly demonstrated that all aspects of biomass utilization must be considered including collection, transportation, storage, burner feeding systems, and combustion mechanisms. A major weakness of all the biomass combustion devices tested was the feed system. Plugging, bridging, variable moisture content, and safety were major concerns because of the need for reliable automation and because the feeder represented a direct combustible link to the stockpile of biomass. The experimental systems, therefore, required close monitoring when in operation. These factors detracted considerably from the attractiveness of using biomass and were the original reasons that fossil fuels were adopted in place of biomass.

The program confirmed that the development of a useful biomass burner was not straightforward despite the simplicity of building a burner that will burn biomass. Most proven burners have evolved over several generations of trials while many units have been built by innovative farmers or other entrepreneurs and unfortunately failed prematurely. The difficulties that a biomass burner design entails need to be approached with a great deal of realism, innovation, and perseverance with no guarantee of a successful outcome.

The SUKUP burner, designed to burn corn cobs and husks, was an acceptable commercial biomass burner. It performed as specified and has been proven in the agricultural environment. Additional research effort on biomass combustion was therefore difficult to justify unless there remained a very unique aspect requiring development and commercialization looked promising.

The pyrolysis project, using the rotary kiln at the University of Sherbrooke (contract no. 8-1802), demonstrated a problem which can occur when existing installations are used for research for which they were not originally designed. The problems of the kiln seriously affected the outcome of the project and led to an ineffectual examination of pyrolysis technology for agricultural residues.

Traditional hay and straw handling systems were changing significantly during the course of the program with the advent of large bale and stack handling equipment. Large amounts of biomass could be handled with a minimum of manual labor and many farms rapidly adopted this technology for this reason. Large bales proved unsuited to automated feeding systems unless the bale was dissembled before it was fed to the combustor. Combustion control was lost for a few minutes after the whole large bale was fed because the air contained in the bale caused the burner to overheat and fail. Most successful systems, such as the European designs, were based on the small bale. Introduction of biomass combustion would therefore involve either a reinvestment in small bale technology or extra investment if large bales were to be used.

The best time to collect a biomass residue for energy is at harvest time, usually before it hits the ground. However, the economic attractiveness of gathering biomass cannot compare to the economics of gathering a crop. For example, harvesting corn can represent a gross income of $1000 per hour. It is therefore difficult to justify much effort to gather a low-value biomass until the harvest is completed.

The program demonstrated that a full scale feeding trial of biomass processing residues is necessary before any claims can be made about the use of the materials as animal feed. Animals can initially be fooled and fed almost anything, even going as far as to artificially mask the flavour. Eventually, if the feed is not beneficial to them, they will reject it or reduce their feed intake resulting in reduced weight gains and economic losses to the farmer. One example, milkweed residues, looked like a suitable animal feed but the animals rejected it because it became toxic to their system.

CONCLUSION

Agriculture has the potential to become more energy efficient and, theoretically, self-sufficient, but there is little economic incentive to do so. Alternative energy sources have to compete not only with the relatively low cost of oil, propane, natural gas, and electricity but also with the convenience of their utilization and labour saving aspects. Biomass has inconsistent quality and availability; It may vary from one year to the next and can deteriorate over a short period of time. Petroleum based fuels have stable quality specifications as they must meet stringent specifications and standards. There are few quality control STANDARDS POSSIBLE for biomass, making commercial exploitation much more difficult.

The energy crops and biomass utilization portion of the ERDAF program analyzed the potential of agriculture to supply all or some of its energy requirements from the biomass produced from agricultural land. A perceived abundance of waste biomass, surplus land suitable for energy crop production, and the existence of applicable technology made agriculture an obvious choice for renewable energy research. The program allowed those involved to critically examine the concept of biomass energy production in agriculture from a holistic perspective. Utilization of any agricultural biomass is fraught with problems and a wide range of constraints including technological, economic, and biological. Of these, only the technological are amenable to solution by investments in research and development.

The work covered in this report varies from the basic analysis of material and products, to crop production, to the development and evaluation of processing equipment. A summary of the most important achievements includes the following:

1. An assessment of the sustained amount of biomass that could be obtained from agriculture while maintaining current levels of food and feed production was made and found little opportunity for renewable energy from biomass for economic sectors outside agriculture.

2. The yields of energy crops, taken in a practical sense, were little different from other agricultural crops. Total biomass yield on a dry matter basis was similar.

3. It was demonstrated that a suitable commercial biomass burner and biomass collection and handling system exists for corn residues and similar materials.

4. The program established that the combustion of agricultural biomass was not without its disadvantages and, in most cases, was not competitive with fossil fuels or electricity.

5. In spite of the benefits of handling biomass in big bale form, the bale must be reduced in size prior to burning to promote good combustion control.

6. Kochia, first considered as an energy crop, was considered further as a new forage crop for saline soils and is part of ongoing research to reclaim saline soils.

7. Pyrolysis of biomass materials proved too sophisticated for energy conversion in the farm sector.

8. The program provided support for the development of chaff collection and utilization. Chaff is being developed as an important alternative cattle feed, a feedstock for ethanol production, and a fuel for large scale combustion for drying field materials. Agronomic benefits and alternative uses for the chaff (other than as cattle feed) will help promote its use on grain farms.

Introducing and integrating energy production into the food and feed production system can create technical, managerial, and economic problems, with a negative impact on agriculture. If agriculture is to become more energy self-sufficient, the relative cost of current energy sources must increase substantially. For the present, energy conservation must continue to be emphasized as the best option to help the industry cope with its energy needs.

REVIEW OF CONTRACTS

A short review of the progress and findings of each contract follows. It should be noted that an important aspect of the program was information development and transfer, and some contracts played a key role in this, even though their scientific contribution may not be significant.

After reading the review on each contract, the reader should be able to determine if there is a need to obtain the contract report for study. The reports are available only in the preferred language of the contractor. A complete list of contracts appears at the end of the report with instructions for obtaining the final reports included. Other reports relating to the program are cited in the reference section.

RESOURCE ASSESSMENT

Contract No. 9-1903

Crop Residue Densification: Technical and Economic Feasibility. Saskatchewan Research Council, Coxworth, E., Coates. W., Zuk, B., Craig, W. and Boerma, H. 1981, 124 pp.

The interest in agricultural biomass for energy prompted this group to examine ways of densifying the biomass to reduce the cost of transportation. Emphasis was given to the amount of energy required for densification and evaluation of recently developed methods. A good summary of the densification practices in Canada, U.S.A., Italy, France, Germany, Denmark, England, Sweden and U.S.S.R. was given. However, soil specialists were concurrently reviewing the amount of straw required for soil conservation and the study expected retained straw requirements to increase, decreasing the amount of biomass available for energy purposes.

Pelletizing, hammermilling, and cubing methods of densifying the residues were examined. Specific equipment capacities, power requirements, and bulk density changes were discussed. Grinding was an unacceptable method of size reduction because of the large power requirements and low capacity. It is interesting to note that many biomass combustion systems require finely ground material for proper combustion, especially at the laboratory or pilot scale.

Energy costs of cubing or pelletizing were not very large but the increased capital cost of the equipment required was not offset by the resulting reduced transportation cost. Many of the systems were developed for wood and a comparison between wood and agricultural residues was made. The handling and hauling costs of hay, straw, and chaff were compared for Saskatchewan based on square and round bales and stacks. It was found that large handling systems were not suitable for biomass transport over long distances. Costs of the various systems, load densities, load sizes, and transportation fuel costs were given.

Systems aspects of biomass harvesting and transporting were examined. Problems such as supply, conversion technologies, and scales of operation each played an important role. Because extensive production systems exist for forages, a comparison was made with forages.

Separation techniques which sorted the residues into components of different feed quality and value were considered. The study also looked at the energy value of the residues comparing them to wood as a reference. An important observation of this work was that chaff was worth pursuing for its feed and agronomic value and the report recommended that a better production system be developed.

Contract No. FR09/1

Assessment of the Potential for a Sustained Energy Supply for the Agriculture and Food System for the British Columbia and Prairie Regions, Canadian Resourcecon Ltd., 1982, Volume I, 192 pp and Volume II, 178 pp.

The contract objective was to examine the availability of agricultural residues for use as an energy source for Western Canada. It was found that the use of crop residues for energy was highly constrained by the need to retain the residues on the land for wind and water erosion protection and nutrient supply in the brown soil zones of the prairies. Only a few regions were considered to have a surplus of residues. Flax straw was considered an exception because of its resistance to natural degradation. Common practice is to burn flax straw in the field. Chaff was identified as having good potential as a combustible energy source with minimal effects on erosion control and soil productivity and can thus be considered as surplus material.

The availability of natural gas precluded the use of residues for space heating in most cases. Corn stover for drying was considered viable because of the need to dry corn grown as a grain crop. The study noted that grain yields vary considerably from year to year and that the residues may not necessarily be a reliable source of energy. Vegetable residues were shown to have no potential as an energy source because the high soil nutrient demands of vegetables make it best to return the residues to the soil. Also, storage of these residues was not practical. A possible exception to this was potato culls but these are already used as animal feed with a higher value than as an energy feedstock.

Use of food processing wastes contained in dilute waste streams would require practical anaerobic digestion or fermentation technology and progress in the development of these technologies. The slurries generally had a greater value as animal feed. Anaerobic digestion of animal wastes could not compete with natural gas and environmental incentives such as odour control on the prairies were small, making the implementation of this technology unlikely. Returning the manure to the land represented an indirect conservation of energy, displacing chemical fertilizer that otherwise would have to be manufactured.

Grain screenings had a high value as animal feed. Refuse screenings have future energy potential depending on the development of processes for the conversion of cellulose to ethanol.

Increased use of intensive crop production systems was considered as it could release land for energy crop production. However, little economic incentive existed considering the current returns to agriculture. Vast tracts of land suitable for expanded production, such as in the Peace River area, were identified. These areas were lower class land with a high development cost somewhat offset by the wood gained from clearing the land.

An obvious conclusion not stated in the report was that agriculture operates in an inherent and natural closed system. Nearly all of its byproducts are used to maintain primary production whether the outputs are in the the form of grain or livestock. There must be sufficient economic incentive to overcome the traditional (i.e. closed system) benefits of the byproducts for agricultural biomass to be attractive for energy purposes.

Contract No. ER09/2

Assessment of the Potential for a Sustained Energy Supply from the Ontario Agriculture and Food System, Deloitte Haskins+Sells Associates, Broadwith, R.A., 1982, 175 pp.

The report projected the potential energy production from agriculture in Ontario as being equivalent to only 2 or 3 days of the current oil production of Alberta. If crops familiar to farmers were grown for ethanol production, little or no net energy gain would be realized from large centralized plants requiring considerable feedstock transportation. Speciality energy crops appeared to have limited potential if marginal land was used. However, more firm data on actual yields and costs of production need to be established.

Northern Ontario has large tracts of land that could be developed and used for agriculture in competition with forestry. It would appear more economically advantageous to expand the current land base in southern Ontario and improve its productivity. The report discussed the current utilization level of agricultural land and the increases that could be achieved through better field layout.

The research found that most food and feed byproducts which could be considered for ethanol production were currently used as livestock feed. Most ethanol production wastes differed from their original form as the protein was more concentrated, the moisture content was higher, and the carbohydrates were removed in the conversion to alcohol.

Different conversion technologies were discussed with respect to the available types of biomass. In general, all required more development before they would be practical and economical to use.

Contract No. ER09/3

Evaluation du potential pour un approvisionnement energerique de soutien du systeme alimentaire en agricole, Roche Associes Ltee, Jacob, G., 1982, 175 pp.

This report was similar to ER09/2 but covered the province of Quebec. One of the goals of the Quebec government at the time was to

become more agriculturally self-sufficient. This desire dictated that the incentives for increased production gave priority to food and feed production as opposed to energy production. This study relied heavily on the publication "Nourrir le Quebec" published by the provincial agricultural ministry in 1981.

The report discussed the amount of each agricultural biomass that could be safely removed and converted to energy. It was concluded that about half of the cellulosic residues could be removed without harming the soil if crops were properly rotated. A disaggregate analysis method was not used as the same factors were used throughout the study.

The available residues were straw, chaff, and corn stover with oat straw predominating because of the popularity of the crop. The production of biogas from hog manure would be immediately profitable and provide significant amounts of energy in Quebec because of the size and concentration of the hog population. Quebec had an extensive surplus of whey and a good opportunity existed to utilize this for energy.

A major constraint identified was that most of the production of bioenergy would be seasonal, requiring a large scale conversion facility to be profitable. The land base for production appeared limited and only marginal land could potentially supply additional biomass for energy.

Contract No. ER09/4

Assessment of the Potential for a Sustained Energy Supply for the Agriculture and Food System for the Maritime Region, Technical University of Nova Scotia, Ben-Abdallah, N., Al-Taweel, A. M. and Procos, D., 1982, 192 pp.

This report covered the biomass potential in the provinces of New Brunswick, Nova Scotia and Prince Edward Island. Newfoundland was not considered. Anaerobically digested animal manure was identified as a potential energy source for large livestock operations. Small digester operations were not viable and manure could not be economically transported to larger centralized facilities. Since few large operations existed, the potential amount of energy from this source was limited.

Food and feed processing wastes also presented a transportation problem and quantities were too small to be significant. Potato culls were the only food processing waste available in significant quantities in Prince Edward Island and northwest New Brunswick. Ethanol production was the best conversion alternative for using potato culls. Again, the transportation cost and their economic value as a cattle feed must be considered.

Cereal crop straw was found to be the major potential feedstock in some regions in the Maritimes. Direct combustion was considered the best alternative. However, combustion required a high investment and was

quite dependent on the heating application. Energy plantations were a possibility because of the amount of idle or marginal land available, LAND which could provide about 20 per cent of the primary energy requirement for agriculture. Another alternative was the production of wood chips which could produce energy at about half the cost of oil.

In general, it was concluded that a more detailed study was warranted in the area of biomass concentration with emphasis on energy plantations. Economic, social, environmental, and land use aspects of energy plantations requires further study.

DIRECT COMBUSTION

Contract No. 8-1801

Evaluation of a system utilizing biomass sources for crop drying and heating on the farm. Lynhurst Farms Ltd. Peill, J.E., 1978, 12 pp.

Direct combustion of straw was examined as a possible on-farm energy source to alleviate increasing energy costs for a farm located in the Annapolis Valley of Nova Scotia. At the same time, the local increase in straw yield was causing a disposal problem. A large bale burner developed in Germany was imported and installed to dry grain and heat a 250 sow farrow-to-finish complex. Large round bales were loaded into the burner directly without prior chopping or pelletizing. The level of mechanization offered by the large bale handling equipment was attractive to farmers.

The burner had a firebrick lining, a steel after-burner, and an airlock for on-the-go refueling of one complete bale. Primary combustion occurred in the bottom half of the unit and secondary combustion, aided by additional air, occurred in the after-burner tube. A support cone straddling the after-burner in the center of the unit prevented the bale from settling directly onto the after-burner. The burner, rated at 4 GJ per hour by the manufacturer, was a prototype and had not been tested for any appreciable length of time. After the first year of operation, the liner and the after-burner had to be replaced since they had failed under the temperatures that existed in the burner. Subsequent experience with the system enabled an improvement to be made to the life span of these components but longevity concerns were never completely resolved.

Although the system was relatively easy to operate, the burner was shut down once a day to remove slag buildup. Each hour, a new bale was added to maintain operation at full capacity. A gas-air heat exchanger for grain drying and a gas-water heat exchanger for water heating was used. The grain drying heat exchanger overheated the drying air and the system was modified to dilute the drying air with recirculated discharged air to reduce the temperature.

Different methods of storing bales were examined. Piling the bales at the edge of the field immediately after baling them and covering them with a tarp was the best method of storage. Bales would then be moved to

a temporary storage prior to being used. Straw needed protection from the rain for the combustion system to work efficiently as unprotected bales absorbed too much moisture to be able to generate sufficient heat.

This project established that, in some circumstances, straw combustion would be a practical source of heat and further development efforts to overcome some of the operating problems were warranted. An analysis of the economics of substituting straw for oil or propane was made. It was found that 0.4 kg of straw were required for every kg of water removed from the grain when the exhaust gases were used directly for drying. For water heating, the loss of efficiency would be greater because a heat exchanger would be required. During the two years of operation, 3,291 tonnes of grain were dried. The annual consumption of straw ON this farm indicated that the system would break even assuming that there were no alternative economic uses for the straw. There was an economic advantage to remove the straw on this particular farm because of the cost of straw incorporation in the soil. The wet maritime climate necessitated the protection of the bales, an unnecessary procedure for other parts of Canada. The project was continued in a subsequent contract (No. ER12).

Contract No. ER07

Testing and Assessment of the SUKUP Biomaster Crop Residue Drying System. Forintek Canada Corp. Huffman, D.R., and L'Ecuyer, A. 1985, 120 pp.

A detailed qualitative and quantitative evaluation of a commercially available SUKUP agricultural residue burning system was performed utilizing oat straw, timothy straw, and low and high moisture corn stover. Technical performance was monitored, combustion products analyzed, thermal efficiency established, output capacity determined, and a material and energy balance made. The ease of operation, degree of supervision, and safety were also evaluated. This project was undertaken to substantiate the burner's specifications and performance as it appeared to fulfill the agricultural industry's requirements for a reliable and inexpensive biomass combustion system.

The vertical combustor unit was a refractory lined single chamber with cyclonic overfire air inducted by the main dryer fan. Combustion products are passed through a lava rock filter and mixed with tempering air before being ducted to a grain dryer. To permit process monitoring, ducts were installed on the inlet and outlet gas flow passages. Fuel feed was automatically controlled in response to an adjustable thermostat activated by a thermocouple located in the top of the combustion chamber. The SUKUP combustor was found to satisfactorily burn a variety of low moisture crop residues to produce hot gas output for heating or drying applications.

Two modes of fuel feeding were evaluated. Automatic cyclic feeding resulted in cyclic variations in temperature while continuous feeding gave higher temperatures and eliminated the short regular cycles. Continuous feeding also reduced particulate and carbon dioxide

emissions. During automatic cyclic operation, combustor capacity and efficiency were similar for the three agricultural residues tested at feedrates of 76 kg/h and 73% moisture. This corresponds to an energy input of 1.4 GJ/h and an energy output of 1.0 GJ/h.

Some improvements were suggested, such as a feed system control to enhance combustion stability and reduce emissions, and a redesign of the ash removal system. Overall, the unit was considered suitable for applications involving drying and space heating using agricultural residues. The SUKUP is available on the market and performs according to the manufacturer's literature.

An advantage of this system was that it was designed and constructed by a firm well experienced in manufacturing agricultural grain drying and handling equipment. The SUKUP was also one of the few burners able to handle agricultural residue without preprocessing of the feedstock.

CONTRACT NO. ER12

Development of a Feed Mechanism for Straw Burners. Biomass Combustion Ltd. Peill, J.E. 1984, 19 pp.

In contract no. 8-1801, a large round bale straw burner was evaluated. It was found that loading a complete bale at a time into the burner was not satisfactory because of poor combustion control immediately after loading. This project was to develop a mechanism to feed the straw from the bale into the burner on a continuous basis.

The report carefully listed the objectives of the project but the system developed was not adequately described. The bales were first chopped up and then fed into the side of the combustion chamber with a variable speed auger. Back-fire protection was provided by a compressed straw plug at the end of the stoker tube which acted as an airlock during refueling, a thermostatically controlled flood system on the stoker auger, and a metal trap door between the stoker auger and the crossfeed auger. Pictures of the system were the only other description given.

An energy balance for two operating seasons was given in terms of gross energy output. A comparison was made to a similar propane fired system, giving both costs and energy use. It was found that the chopped straw feedstock and feeder reduced the labour demands on the operator and generally worked satisfactorily.

It was concluded that the unit would have to operate more than 1900 hours per year to break even. This length of time was more than would be required to dry grain on a farm necessitating an additional use, such as space heating, before it would be economically advantageous. The main limitation was the high capital cost compared to the cost of a propane system. The contractor abandoned his plans for manufacturing additional units for sale because of poor market prospects.

The report was of little value other than to account for the work done as insufficient information was presented for anyone to duplicate the work.

Contract No. ER13

Construction and Evaluation of Small Bale Gasifier, Biomass Combustion Ltd. Peill, J.E. 1984, 11 pp.

A small bale gasifier was built to provide sensible heat for a farm structure. The report had a similar shortcoming to the previous contract (no. ER12) in that the design criteria was well documented but a detailed description of the components was not included. An energy balance was made by comparing energy required to heat the same building with straw and with #2 fuel oil. Some of the shortcomings of this method were discussed in the report.

The operation of the unit was reasonably successful with a few modifications required to prevent deterioration of certain components. Some development was required before the gasifier would be ready for commercialization. An economic analysis found that the oil system was cheaper but this depended very much on the cost or value placed on the straw. In this analysis, the market value of straw was used.

The report was of little value other than to account for the work done as insufficient information was presented for anyone to benefit from it.

Contract No. ER36

Utilisation des residues de pommes comme combustible, Bernier, Richard & Associes Inc., Kalnins, R. and Lalonde, C., 1985, 115 pp.

The objective was to study the feasibility of using apple wastes from juice processing to provide a fuel for juice pasteurization and container sterilization. The nutritive value of the residue consisting of skins, cores, and pits, is too low to use as animal feed and it is currently trucked to dump sites or used as fertilizer.

The laboratory study determined the physical and chemical characteristics of the residues and their heating capacity at different moisture contents. The moisture content of the residue was initially 80%. At 50% moisture content, the heating value was close to that of wood. A heating value of 5,750 kcal/kg at 20% moisture was found.

The residues were first dried using an alfalfa drier. A combustion experiment using a full size multifuel boiler was conducted. Large quantities of ash were produced requiring that the ash must be removed every sixteen hours to maintain efficiency. The maximum moisture content for the drying/combustion system was 20% if sufficient energy was to be recovered on a continuous basis.

If the apple juice company were to burn all of the residue produced. The energy released would produce all of the steam required for the operation. A capital investment of about $500,000 would be recovered in 3.2 years.

Contract No. ER37

Development and Evaluation of a Concentric Vortex Chaff Furnace Using Chaff as the Primary Feedstock for Grain Drying and Space Heating. Canadian Resourcecon (1983) Limited, Coape-Arnold,T., 1985, 151 pp.

A literature review indicated that large amounts of chaff were available in western Canada and that this material could be removed since it was not required for soil conservation. A resource assessment and a furnace design using the energy from chaff to supply heat for grain drying and space heating was undertaken.

The availability of chaff was discussed. The logistics for a complete chaff collection, storage, preparation, and utilization system were examined and described. The economic viability at a number of farms where a system might be applicable for grain drying and space heating was studied.

The literature describing existing agricultural biomass furnaces was reviewed and it was concluded that no suitable chaff burner existed in North America. A design of a concentric vortex burner developed at Iowa State University was scaled down and redesigned for chaff. It was concluded that a burner with an output of 2.5 GJ/h would be required to match the output of most on-farm dryers and space heating loads. A burner was not built due to termination of the funding for the program and poor commercial prospects for the unit.

The study served as a comprehensive search and evaluation of the state-of-the-art of biomass combustion in actual use on Canadian farms. The problems of existing units included low combustion efficiency, fuel handling, and poor reliability of furnace and boiler materials. Several existing units were farmer built and had not benefited from current engineering knowledge.

Since this report was submitted, considerable development in the use of chaff for animal feed has taken place. Agronomic benefits from better weed control through the removal of the weed seeds in the chaff provides incentive for grain growers to remove chaff and utilize its energy value. The study examined the economics of competing energy sources available to grain farmers (such as natural gas and propane) and found that it was difficult for biomass combustion to compete. Therefore, the market potential was found to be quite small for a chaff combustion system.

Contract No. ER38

Development and Evaluation of a Small Scale Gasifier System for Utilizing Farm Wastes, Mayer & Poer Corp. Inc., Mayer, E., 1985.

A small scale gasifier was designed and built based on previous experience of the contractor in building and testing two units. The units were designed to operate on locally available biomass such as

chaff, sunflower hulls, sawdust, and wood chips. The gasifier was a downdraft design with a rotary grate scraper and a cyclone installed to remove the ash from the exhaust as the gas was to be ducted directly to a grain dryer.

The unit for this project was built from mild steel to keep costs to a minimum and facilitate modifications even though mild steel was not a suitable material for the final version. Operation of the system was never fully described or verified. The gasifier was hand fed a pailful at a time requiring constant supervision and making long runs very difficult and costly.

The mild steel deteriorated before the completion of the required tests and the unit had to be rebuilt. At the same time, an automated feed system was planned. All trials had been done using wood rather than agricultural materials and more scientific data gathering and analysis was warranted. These objectives were not realized because the project had used up all the funding on the tests with wood. Due to a reduction in the program and a lowering of priority for combustion research, no additional funding was available and the project was terminated.

The contract was terminated without an acceptable final report. The gasifier demonstrated that it was relatively easy to build a functioning burner but it was difficult to make a commercially viable product, a fact usually overlooked by entrepreneurs. In spite of this, the burner had some unique features worth pursuing should the energy situation change.

PYROLYSIS

Contract No. 8-1802

Pyrolysis of agricultural biomass as a source of fuels for Canadian farm operations. Sandwell Beak Research Group, Grandbois, M., 1979, 80 pp.

The purpose was to assess the feasibility of pyrolysis of agricultural residues as a process for on-farm fuel production. The project began with a literature review, but monitoring current publications proved more valuable as much of the information of interest to the project was being generated at the time. It was found that very little had been published in Canada and, more specifically, little work had been done on the pyrolysis of agricultural residues.

At the University of Sherbrooke, a rotary kiln originally obtained for pyrolysis of peat was used to perform preliminary tests on corn stover and oat straw. Corn stover was collected and artificially dried to 8% moisture and the straw was obtained at approximately 5% moisture. The samples were finely ground and analyzed for elemental carbon, hydrogen, oxygen, sulfur, nitrogen, moisture, ash content, and volatile matter.

A further analysis of several metals was also made because of the potential role metallic catalysts can play in the conversion process. The gas and char output were analyzed. Variations in the feedstock made precise analysis difficult. The equipment had originally been set up for peat pyrolysis and some modifications were necessary to feed the agricultural material into the kiln. A maximum feed rate of 10 kg/h for the stover and 2.2 kg/h for the oat straw was obtained. An energy balance was made and a thermal efficiency of 62% to 65% was attained. The char produced had an energy content similar to bituminous coal and the gas about one third that of natural gas.

The report presented a discussion on some possible uses of the end products. It concluded that the corn stover must be dried before it could be fed to the kiln as its harvest moisture content would be too high. Maximum feedstock moisture content which could be handled was 10%.

It was concluded that pyrolysis had good potential for the production of a storable fuel suitable for heating. An overall efficiency of 77% was considered satisfactory. A recommendation was made to carry on with the work and that further characterization of the products would be useful. Work was continued in subsequent contract (No. 9-1902).

Contract No. 8-1818

Gasification of harvest residues for the production of energy, Inst. de recherche de l'Hydro-Quebec, Chamberland, A. 1979, 56 pp.

The objective was to study the theoretical possibility of using gasification equipment in the farm sector to supply energy from crop residues for various farm operations. A grain farm of 2350 hectares in western Canada and a corn farm of 405 hectares in Quebec were evaluated. Gasification was chosen for this study because of its relatively high efficiency and versatility in the production of gas as a substitute for conventional sources of energy. This report results from only a theoretical analysis; experimental work was not conducted.

The rationale for the choice of each representative farm was presented. The grain farm in western Canada did not appear attractive because of the high cost of collecting the cereal straw, the seasonal requirement for drying heat, and the small amount of grain requiring drying. In Quebec, the combination of grain drying and greenhouse heating was the most economically attractive option and an actual farm was selected for detailed economic analysis. Several gasifiers were investigated and the Duvant was considered as the most appropriate choice.

The report concludes that gasification technology suitable for farm applications exists but economics were the main caveat against adoption. Despite the abundance of residues in agriculture, it was not practical to gather them for conversion to an energy source.

Actual test data was not generated by this project. All the conclusions were based upon anticipated system performance and problems of overheating and other causes of premature failure were not assessed. The report failed to detail any useful new developments but served as an update in gasification technology.

Contract No. 9-1902

Pyrolysis of agricultural biomass as a source of fuels for Canadian farm operations Phase II. Sandwell Beak Research Group, Farrell K. 1981, 40 pp.

This project was the continuation of contract No. 8-1802 which made a preliminary assessment of pyrolysis using the rotary kiln at the University of Sherbrooke. The initial work had given positive results but the results from this subsequent work were rather discouraging. A series of experiments using wheat straw and corn stover were designed to provide the data required to design a system and prepare cost estimates. A serious problem resulted when tars condensed in the cooling sections of the rotary kiln, causing the tars to stick to the walls of the char hopper and eventually plug the hopper. The gas lines also plugged and accurate gas collection was not possible. A mass balance could only be obtained by dismantling the unit. The desired 85% mass balance could not be achieved. Another problem encountered was that insufficient gas was produced to feed back to the kiln to maintain the pyrolysis reaction and to offset the various process heat losses in the configuration. It was concluded that major changes to the kiln would be required to make it suitable for pyrolysis of agricultural residues. The process was thermally inefficient because the indirect heating and the low density of agricultural residues made it difficult to operate the pyrolyzer in a self-sustaining mode. The char produced was of low quality and not easily storable. A well trained operator would be required to operate the system. The contractor felt, however, that a newly designed feed system was capable of handling agricultural materials, except for corn stover which required removal of the unchopped leafy material.

Vacuum pyrolysis was used in the study and showed a good potential for the production of chemical feedstocks or liquid fuels. Because these products would require extensive upgrading, they had limited commercial value. It was therefore concluded that rotary kilns and, in particular, the one tested, were not suitable for converting agricultural residues. The available literature on gasification and gasifiers was then reviewed to seek a solution to the problems encountered.

ENERGY CROPS

Contract No. ER01

Assessment of Lunaria as a Prospective Crop for Fuels and Industrial Oils. Enersearch. Saskatchewan Research Council. Craig, W. and Coxworth, E. 1984. 15 pp.

Lunaria, more commonly known as Honesty or the Silver Dollar Plant, has been grown commercially for ornamental use or dried flower

arrangements. The plant grows to a height of a meter and can produce 5500 kg/ha of seed. The seed is found in flat, round, silvery pods. The objectives were to determine the quantity and value of the extractable oil and the residual meal, and establish the agronomics of the plant.

A sample of seeds was milled and hexane extracted to recover the oil. The seeds had an average oil content of 37.6%. The oil had properties similar to canola and sunflower and it was anticipated that, if used as a diesel extender, it would behave similarly to canola oil. It was also speculated that lunaria would serve as a alternative source of high erucic acid for the chemical industry, eliminating the need to produce high erucic acid rapeseed and reducing the potential for contamination of low erucic acid rapeseed for food uses in the transportation and handling system.

Several attempts to establish field trails were not successful and the potential yield could not be confirmed. Although reportedly an annual plant, it was actually a biennial and the seed required vernalization before germination. An annual variety was found that did not require vernalization but it required long photo periods to induce flowering. It was concluded that lunaria could not be grown satisfactorily in Saskatchewan as the biennial variety apparently could not survive the Saskatchewan winters.

These findings were preliminary as only one year of agronomic data was obtained.

Contract No. ER02

Assessment of Milkweed as a Potential Renewable Energy Crop, Enersearch, Saskatchewan Research Council. Craig, W. and Coxworth, E. 1985. 34 pp.

Milkweed is a hardy perennial plant which demonstrated potential as a cultivated crop for marginal lands in agronomic screening trials in the United States. It contains an extractable whole plant oil which can be converted to a specification liquid fuel using a conventional refinery process. The residual biomass was initially considered to have potential for a ruminant animal feed.

The Plant Resources Institute of Salt Lake City had initiated research to establish the agronomic practices for cultivating milkweed. Enersearch worked in conjunction with them to establish stands both from seeds and root cuttings in several locations. Various weed control and cultivation methods were tried. Milkweed could be successfully grown under Saskatchewan conditions giving a yield of 3.5 to 4.0 tonnes of dry matter per hectare per year.

The whole plant oil present throughout the entire plant was removed by solvent extraction after the plant had been dried and hammermilled. Different levels of plant maturity and types of solvents were tested and described. In some pilot plant extractions, it was found that the extraction efficiency was not very high compared to other oilseed extractions.

Initial feeding trials with mice demonstrated a gradual reduction in feed intake and growth rate as the level of milkweed was increased in their diet. Subsequent feeding trials with ruminants found that the presence of a toxic substance in the original milkweed biomass caused the animals to reject the feed completely after a few days. The toxic material could be removed by exhaustive alcohol extraction. However, because of the poor efficiency in the oil extraction, too much toxin would remain. The crop was therefore found unacceptable as an animal feed.

A variety of physical separation processes for the fiber and protein were attempted. A protein enriched material could not be successfully obtained. The material was also evaluated as a fermentation feedstock with little success, again attributed to toxicity effects on the yeast. The recovered fibers were evaluated as a kraft pulping feedstock but, because of fiber strength and cost, it was not economically attractive.

The research demonstrated that it was technically possible to grow, harvest, and process milkweed but that the value of the whole plant oil could not support milkweed production for energy purposes. Further refinements and improvements could not be justified from an energy or economic perspective.

Contract No. ER05

Assessment of the Potential of Growing Unconventional "Energy Crops" or Multiuse Crops on Saline or Marginal Land. Saskatchewan Research Council, Sosulski, K. and Coxworth, E. Volumes I,II and III, 33,142 and 73 pp.

Volume I: Crop Yields and Composition

Twelve slender wheat grass types, Jerusalem artichoke, and fodder beets were grown at several sites in Saskatchewan to evaluate their cellulose and fermentable sugar production. Quality characteristics such as protein content and digestibility were noted as well as tolerance to saline soil conditions. Problems such as drought, hail, and excessive weed competition made determination of plant characteristics difficult and experimental results inconclusive. The agronomic trials were not of sufficient duration to overcome these problems. The data presented, therefore, must be carefully interpreted in the context of the experimental limitations under which the information was obtained. General conclusions are therefore not feasible.

Volume II: Cellulolytic Hydrolysis of selected Forages and Recovery of Enzyme Proteins

The objective was to investigate the potential of salt tolerant crops as sources of carbohydrates for the fermentation process and for protein byproducts for animal feed. The crops considered were alfalfa, slender wheat grass, Jerusalem artichoke tops, and kochia. The effect of maturity, enzyme level, and time of hydrolysis on the type and yield

of sugars were examined. Much of the work focused on protein separation and recovery at various stages of processing. Sugars and other soluble residual components were isolated from forage materials. The fermentation potential of natural and enzymatically hydrolyzed material was investigated using several strains of yeast. As found in other studies, the presence of inhibitors limited the fermentability and methods to remove the inhibitors were too expensive for commercialization. Several recommendations for future experiments were made. Methods of recovering proteins from the fermentation products were assessed and discussed. The final relationship examined was the correlation of cellulase digestion with in-vitro digestible organic matter. As much of this work was exploratory, considerable information was generated but more work would be necessary to achieve more definite conclusions.

Volume III: Fundamental Chemistry and Biology of Forages and Crop Residues

The original intention was to obtain a better understanding of the cell wall structures of forages and crop residues before and after chemical, physical, or enzymatic processing, and before and after digestion by cellulolytic microorganisms. Following project initiation, several groups reported results on this subject; these were included in the discussion. The work was reported in three parts: the structure of cell walls of forages and mechanisms of treatments to improve enzyme hydrolysis, a literature review of microscopy studies, and the effects of plant phenolic acids on cellulolytic microorganisms and higher plants. The conversion of cellulose to glucose was not as complete as desired; considerable optimization of the process is required. Ammonia freeze-explosion and steam explosion were the best pretreatment methods and merit further study. It was concluded that a method combining a physical treatment to mechanically expose a large surface area with an effective chemical treatment would be the most applicable method for agricultural biomass hydrolysis.

The report contained a detailed discussion on the bonding of cellulose, lignin, and hemi-cellulose based on recent findings resulting from light and electron microscopy work. Phenolic acids, which are a common constituent of grass and legume forages, were found to cause problems in the growth of bacteria, fungi, and vascular plants and to be affected by the type of pretreatment method. The report concluded that it may be necessary to identify the main types of phenolics produced and test the effect of phenolics on the reaction intended.

Contract No. ER20

Development of Cultivation of Jerusalem Artichokes for an Energy Crop, Sunroot Energy Ltd., Billingsley, P.W. and Billingsley, R.W., 1985, 65 pp.

Jerusalem artichokes had been widely grown in North America but reliable data on field scale agronomic practices was lacking. This project was undertaken to establish more reliable data on the agronomic practices required for the field production of Jerusalem artichokes, the yields, and the associated costs.

Agronomic trials were undertaken at four Ontario locations; Orton, Belwood, Kemptville, and Brantford. The common soil type was a sandy loam. The treatment of the tubers for planting was described; they were sectioned much like seed potatoes. The equipment used for harvesting the artichoke tubers was quite similar to that used for potatoes with some minor modifications.

As part of the test, the tops were also harvested because of their potential value for sugar, fiber, and cattle feed. Standard forage harvesting equipment was used with virtually no modification.

The crop was harvested at various times of the year to determine the maximum extension of the harvest season. Extending the harvest season would reduce the need for storage and provide feedstock to an alcohol plant over a longer period. Different tuber storage methods were examined. Stalks, tubers, and stillage were fed to cattle and swine for preliminary performance assessment.

Yields of 55 to 60 tonnes per hectare were obtained for the tubers with similar yields for the tops. Production costs of $2400 per hectare for the tubers and $630 per hectare for the tops were reported. Either the tubers or the tops could be harvested but the tubers gave the greater yield and flexibility of harvest times. The report included several tables which provided detailed data on the results. It should be noted that one outcome of this work was the identification of a potential market for special sugars from Jerusalem artichoke in Japan which is being actively pursued.

Contract No.ER23

Rye-Corn Sequences for Biomass Production, University of Guelph, Daynard, T.B., Tollenaar, M., Vyn, T.J., Dekker, J.H., and Muldoon, J.F., 1985, 79 pp.

Field trials were conducted for three years to evaluate the potential biomass productivity of a winter rye/corn double crop sequence in southern Ontario. Test were conducted to evaluate the effects of planting dates, harvesting dates, cultivars, tillage practices, and herbicide applications on winter rye biomass yield and corn growth, biomass yield, and cropping effects on soil physical properties. Tests were conducted to evaluate sunflower and forage sorghum for inclusion in a double-crop sequence with winter rye. Studies were conducted to provide information on procedures for storage and utilization of the wet biomass, economics, and energy ratios for a rye-corn double-crop sequence grown for biomass. This work was done in conjunction with other ongoing work on improving soil structure using rye and different tillage systems for corn.

Biomass yields of 14-21 t/ha were obtained with double cropping. A serious reduction in corn yield was found when it was planted by no-till methods into rye stubble and further investigation concluded

that the yield reduction was due to root related factors. Therefore, it was recommended that the winter rye-corn cropping sequence for biomass production should not be used. The optimum system developed was harvesting the rye in early May and planting the corn about 2 weeks after spring tillage to protect the corn from the allelopathic effect of the rye. Adequate weed and volunteer cover crop control was available for this system based on commercially available herbicides.

A study of the liquefaction/pyrolysis of low-lignin biomass from rye and corn was done by the Chemical Engineering Department of the University of Toronto. The calorific heat values and the oil yields were determined for both rye and corn demonstrating that the processing techniques existed. Extensive work was not conducted as it was beyond the scope of the project.

An analysis of the economic costs and energy ratios of producing biomass feedstock through the crop sequences involving rye, corn, and, to a lesser degree, forage sorghum and sunflower, was undertaken. The most promising scenario was a small scale on-farm ethanol conversion system integrated with a livestock enterprise. A major consideration was the logistics of moving large amounts of high moisture biomass to a central facility as transportation would be difficult and costly.

The report contains a large amount of data from the field experiments and systems analysis. The information was clearly presented and suitable for additional analysis.

Contract No. ER27

A Study to Evaluate the Potential of Cattail as an Energy Crop, Saskatchewan Research Council, Lakshman, G., 1984, 89 pp.

This report provided a good base of information for consideration of cattails as an energy crop. The location of Canada's energy resources was reviewed to give a perspective on the contribution renewable energy could make in the near term. The relationship between available land for biomass production, food production, and the land base suitable for cattail production was discussed. The practicality of harvesting cattails in the scattered locations where they might be grown was not considered. The conclusion reached was that a definite opportunity existed for utilizing the vast areas of marginal lands, peatlands, and wetlands for energy crop production based on cattails.

In the second part of the report, a scientific evaluation of cattails as a potential energy crop was made. All the information was based on what could be found in the literature as no actual testing was done in this study. Biomass availability, preparation, and characteristics were discussed. In general, the report was positive about the applicability of the crop but the conclusions were only an interpretation of data in the literature.

Harvesting was identified as a key concern and raises considerable skepticism about the viability of cattails as a crop. Harvesters suitable for materials similar to cattails were available but a field trial would be required to assess them properly. Processing cattails into ethanol was also discussed based upon a study conducted by the U.S. Department of Energy. Reference was made to animal feeding trials of cattails.

The report concluded that cattails were a viable energy crop. Few negative aspects of the crop were discussed, seriously detracting from the credibility of the study results and conclusions.

COMMENTS ON THE PROGRAM

The reports submitted by the contractors and summarized in this publication were required to account for funds expended, time spent, and results achieved. Results presented were frequently lacking in scientific detail, a common occurrence when publicly funded research is conducted by the private sector. Contractors frequently had a vested interest protected by the terms of the contract. They may have designed the system and are therefore reluctant to frankly disclose shortcomings and to reveal the full extent of discoveries made during the project. Ironically, the most successful projects were the ones where the contractor had a vested interest in the project. Agricultural experience proved valuable for the contractor to realistically assess the impact of developed technology, a lesson for future contract research programs.

The program frequently took advantage of equipment, facilities, and expertise from related research which, although not ideal, saved costs in doing the work and increased the leverage of the funds invested by the program. Results were usually not optimized for the agricultural situation but provided an indication of performance.

The success of the ERDAF program can be measured by the research continuing without its sponsorship. Kochia, Jerusalem artichoke, and chaff research can be considered successes as developments of these crops and resources have now become part of Agriculture Canada's in-house program and their future contributions will help ensure agriculture's continued high level of productivity and efficiency.

REFERENCES

The following are additional references stemming from the contract work or produced in support of the program.

Hayes, R.D. 1983. Proceedings of the energy research and development in agriculture and food liquid fuels and energy crops contractors review workshop. Eng. Stat. Res. Inst., Agriculture Canada, Ottawa, Rept. No. I-462, 255 pp. (July).

Hayes, R.D., 1982. Availability of crop cellulosics for ethanol production. Royal Society of Canada Proc. Intern. Symp. on Ethanol from Biomass, Winnipeg, 118-41 (Oct.).

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Colwell, H.T.M., April, 1983. The potential for a sustained energy supply from combustible crop residues in the Canadian Agriculture and Food System. Development Policy Directorate, Agriculture Canada, Ottawa.

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Seecharan, R. May, 1984. Determination of the land resource base, biomass production and estimated cost of production for energy crops. Development Policy Directorate, Agriculture Canada, Ottawa.

Published Contract Report Summaries

These reports are available from the Engineering & Statistical Research Centre, Ottawa, Ontario, K1A 0C6 and present a brief summary of the reports from contracts complete up to the time of publication of each report summary.

Van Die, P., 1980. Summary of Agriculture Canada's energy research and development contract reports. Eng. Stat. Res. Inst., Agriculture Canada, Ottawa, Rept. No. I-233, 27 pp. (Nov.).

Feldman, M., 1985. Summary of 1980-83 contract reports of the Energy Research and Development in Agriculture and Food (ERDAF) program. Eng. Stat. Res. Inst., Agriculture Canada, Ottawa, Rept. No. 8124 I-743, 72 pp. (Aug.).

Feldman, M., 1987. Sumary of the 1983-85 contract reports of the Energy Research and development in Agriculture and Food (ERDAF) program. Eng. Stat. Res. Centre, Agriculture Canada, Ottawa, Rept. No. 8124 I-944, 129 pp. (Sept.).

Van Die, P., Stumborg, M. and Miller, J.D. 1988. An assessment of Agriculture Canada's liquid fuels program. Eng. Stat. Res. Centre, Agriculture Canada, Ottawa, Rept. No. C-006, 43 pp. (April).

Van Die, P. 1987. An assessment of Agriculture Canada's anaerobic digestion program. Eng. Stat. Res. Centre, Agriculture Canada, Ottawa, Rept. No. I-933, 73 pp. (May).

LIBRARY RETRIEVAL OF CONTRACTS

Contract reports are available to the public. The loaning of a hard copy and sale of microfiche copies is handled by the National Research Council/Canada Institute for Scientific and Technical Information (CISTI). Hard copies can be obtained on loan and microfiche copies are sold at cost.

When requesting a contract report ask for it by contract file number (see list of contracts), authors, and title.

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Contact:

Library
Agriculture Canada
Ottawa, Ontario K1A 0C5
Tel: (613) 995-7829

In addition to the contract final reports, many scientific and technical publications have resulted from Agriculture Canada's energy program. No attempt was made to document this, consequently a list is not available. However, through searches of the scientific literature most of the publications can be retrieved. Many extension type bulletins and articles were also produced by the extension branches of the provincial governments as part of their mandate to keep the agricultural community informed on new technology.

LIST OF CONTRACTS AND COSTS

Name of Contract	Contractor and Principal Investigator	Duration & File Number	$Amount
Evaluation of a system utilizing biomass sources for crop drying and heating on the farm	Lynhurst Farms Ltd. Mr. J.E. Peill	Jun 78/May 80 8-1801	107,000
Pyrolysis of agricultural biomass as a source of fuels for Canadian farm operations	Sandwell Beak Research Ltd. Mr. M.A. Grandbois	Aug 78/Jan 80 8-1802	44,900
Gasification of harvest residues for the production of energy	Inst. de recherche de l'Hydro-Quebec Mr. L. Boulet	Nov 78/Jun 79 8-1818	21,000
Pyrolysis of agricultural biomass as a source of fuels for Canadian farm operation Phase II	Sandwell Beak Research Ltd. Dr. E. Chornet	Jun 79/Dec 81 9-1902	54,000
Crop residue densification: Technical and Economic Feasibility	Sask. Research Council Dr. E. Coxworth	Oct 78/Jun 81 9-1903	34,500
Assessment of Lunaria as a prospective crop for fuels and industrial oils	Enersearch Sask. Research Council Mr. B. Dykes	Sep 81/Feb 84 ER01	10,000
Assessment of Milkweed as a Potential Renewable Energy Crop	Enersearch Sask. Research Council Mr. B. Dykes	Sep 81/Feb 84 ER02	76,800
Assessment of the potential of growing unconventional "Energy Crops" and Multiuse Crops on Saline or Marginal Land	Sask. Research Council Dr. W. Craig	Apr 81/Mar 85 ER05	470,000
Testing and Assessment of the SUKUP Biomaster Crop Residue Drying System	Forintek Canada Corp. Mr. D. Huffman	Jul 81/Feb 85 ER07	65,500
Assessment of the Potential for a Sustained Energy Supply for the Agriculture and Food System for the British Columbia and Prairie Regions	Canadian Resourcecon Ltd. Mr. D.K. Strang	Mar 82/Aug 82 ER09/1	63,800

LIST OF CONTRACTS (cont.)

Name of Contract	Contractor and Principal Investigator	Duration & File Number	$Amount
Assessment of the Potenttial for a Sustained Energy Supply from the Ontario Agriculture and Food System	Deloitte Haskins and Sells Associates Mr. R.A. Broadwith	Jan 82/Jun 83 ER09/2	43,600
Evaluation du potential pour un approvisionnement energerique de soutien du systeme alimentaire et agricole	Roche Associes Ltee M. G. Thibault	Sep 81/Oct 82 ER09/3	51,200
Assessment of the Potential for a Sustained Energy Supply for the Agriculture and Food System for the Maritime Region	Technical University of Nova Scotia Dr. N. Ben-Abdallah	Feb 82/Jan 83 ER09/4	30,650
Development of a Feed Mechanism for Straw Burners	Biomass Combustion Ltd. Mr. J.E. Peill	Feb 82/May 84 ER12	75,000
Construction and Evaluation of Small Bale Gasifier	Biomass Combustion Ltd. Mr. J.E. Peill	Feb 82/Mar 84 ER13	50,000
Development of Cultivation of Jerusalem Artichokes for an Energy Crop	Sunroot Energy Ltd. Mr. P.W. Billingsley	Apr 82/May 85 ER20	138,000
Rye-Corn Sequences for Biomass Production	University of Guelph Dr. T. Daynard	Apr 83/Apr 86 ER23	198,000
A Study to Evaluate the Potential of Cattail as an Energy Crop	Sask. Research Council Dr. G. Lakshman	Apr 83/Nov 84 ER27	35,900
Utilisation des residues de pomes comme combustible	Bernier, Richard et Associes Inc. M. L. Bourdon	Jan 84/Feb 85 ER36	67,000

LIST OF CONTRACTS (cont.)

Name of Contract	Contractor and Principal Investigator	Duration & File Number	$Amount
Development and Evaluation of a Concentric Vortex Chaff Furnace Using Chaff as the Primary Feedstock for Grain Drying and Space Heating	Canadian Resourcecon (1983) Limited Mr. G.A. Constable	Mar 84/Jul 85 ER37	104,000
Development and Evaluation of a Small Scale Gasifier System for utilizing Farm Wastes	Mayer & Poer Corp. Mr. E. Mayer	Dec 83/Apr 87 ER38	76,800
		TOTAL	$1,817,000